

## Connecting Galaxy Disk and Extended Halo Gas Kinematics

G. G. Kacprzak<sup>1</sup>, C. W. Churchill<sup>1</sup>, C. C. Steidel<sup>2</sup>, D. Ceverino<sup>1</sup>,  
 A. A. Klypin<sup>1</sup>, and M. T. Murphy<sup>3</sup>

**Abstract.** We have explored the galaxy disk/extended halo gas kinematic relationship using rotation curves (Keck/ESI) of ten intermediate redshift galaxies which were selected by MgII halo gas absorption observed in quasar spectra. Previous results of six edge-on galaxies, probed along their major axis, suggest that observed halo gas velocities are consistent with extended disk-like halo rotation at galactocentric distances of 25–72 kpc. Using our new sample, we demonstrate that the gas velocities are by and large not consistent with being directly coupled to the galaxy kinematics. Thus, mechanisms other than co-rotation dynamics (i.e., gas inflow, feedback, galaxy–galaxy interactions, etc.) must be invoked to account for the overall observed kinematics of the halo gas. In order to better understand the dynamic interaction of the galaxy/halo/cosmic web environment, we performed similar mock observations of galaxies and gaseous halos in  $\Lambda$ -CDM cosmological simulations. We discuss an example case of a  $z = 0.92$  galaxy with various orientations probing halo gas at a range of positions. The gas dynamics inferred using simulated quasar absorption lines are consistent with observational data.

### 1. Observations & Simulations of Extended MgII Halo Gas

We have extracted rotation curves from ESI spectra of 10 MgII absorption selected galaxies. The galaxies have a range of inclination and position angles with respect to the quasar line of sight and a range of impact parameters between 26–107 kpc. Figure 1 shows an example case of the quasar field Q0454–220 where  $z_{gal} = 0.48382$  and  $D = 107$  kpc. The extended MgII absorbing gas aligns with one side of the galaxy rotation curve. Interestingly, the clouds are blended together, which is suggestive that the gas exhibits some form of organized motion (e.g., Figure 1b). In fact, in all but one case, we find the absorbing gas aligns with one side of the rotation curves. However, with this diverse sample, *disk-like halo rotation models cannot reproduce the observed halo gas velocity spread. Thus, disk-like halo rotation does not seem to dominate over infall and outflow kinematic contributions as was previously suggested* (Steidel et al. 2002).

Such discrepancies with the simple models have motivated us to investigate the connection between disk/halo/IGM gas in cosmological simulations of galaxy formation. The simulations are performed using the Eulerian Gas dynamics plus

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<sup>1</sup>New Mexico State University, Las Cruces, NM 88003

<sup>2</sup>Caltech, Pasadena, CA 91125

<sup>3</sup>Swinburne University of Technology, Hawthorn, Victoria 3122, Australia

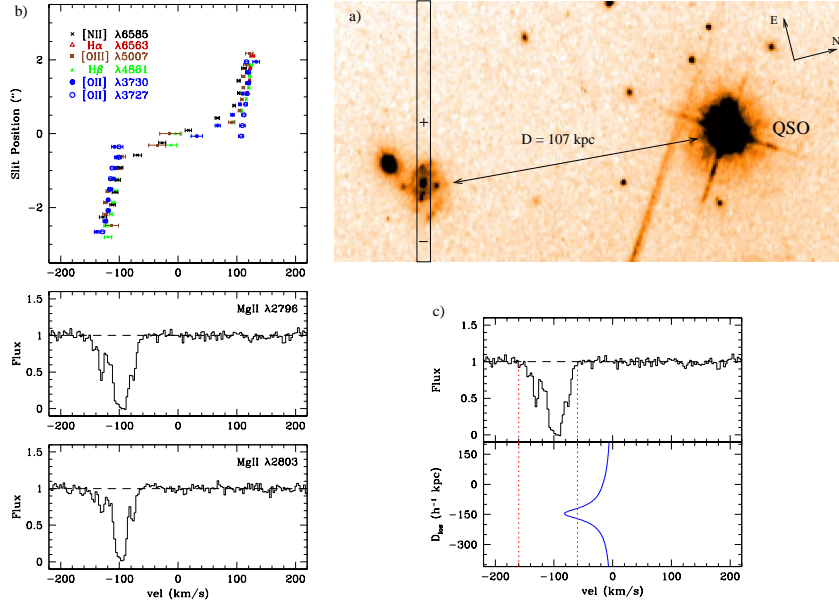


Figure 1. — a) WFPC2  $30 \times 15''$  image of the quasar field. The “+” and “-” indicate positive and negative arcseconds along the slit relative to the center of the galaxy. — b) (upper) Emission line rotation curves of the galaxy obtained with ESI. (lower) HIRES quasar spectrum of the MgII absorbing gas. — c) (upper) MgII 2796 absorption kinematics. (lower) The extended disk model of halo velocity as a function of position along the line of sight, where  $D_{los} = 0$  occurs where the line of sight intersects the extrapolated disk mid-plane. The lack of velocity overlap between the model and the observed absorbing gas reveals that disk-like halo rotation cannot account for the total gas kinematics.

N-body Adaptive Refinement Tree (ART) code (Kravtsov et al. 1997). We ran mock quasar sightlines through the simulations sampling every 10 kpc in a 80 kpc grid around the galaxies. Approximately 30% of the sightlines, primarily those probing along the major axes, are consistent with disk-like rotation. Although it naively appears that the absorption kinematics are consistent with disk rotation, inspection of the simulations reveals that the gas does not necessarily co-rotate with the galaxies. In 70% of sightlines, simple models of disk rotation fail to reproduce the MgII absorption velocities and velocity spreads. Thus, we find that, statistically, the kinematics of halo gas in cosmological simulations are not inconsistent with observed halo gas kinematics. Simulations suggest that stellar winds, SNe, minor mergers/harassments, and cool filament gas inflows all contribute to the dynamics of the halo gas. The dynamic contribution of all of these mechanisms are dependent on the galactocentric distance as well as the evolutionary state (quiescent or star forming) of the host galaxy.

## References

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 Steidel, C. C., et al. 2002, ApJ, 570, 526